DIAGNOSTIC AND FEASIBILITY STUDY of GRAND LAKE O' THE CHEROKEES

PHASE I OF A CLEAN LAKES PROJECT

Final Report

Prepared By:

Oklahoma Water Resources Board
Water Quality Programs Division
Post Office Box 150
Oklahoma City, Oklahoma 73101-0150

Oklahoma State University
Water Quality Research Lab
426 Life Science West
Stillwater, Oklahoma 74078-0459

10 March 1995

Abstract

Title of Study: DIAGNOSTIC-FEASIBILITY STUDY OF WATER QUALITY IN GRAND LAKE, OKLAHOMA

Scope and Method of Study: A Phase 1 Diagnostic-Feasibility study was initiated to determine the temporal and spatial distribution of levels of metals and nutrients in the water column and metals in the sediment of Grand Lake. The spatial and temporal distribution of nutrients were determined by analysis of nitrogen and phosphorus in samples collected monthly from sampling stations along a gradient from the upper to lower end of the reservior. The trophic status of the reservior was evaluated by a combination of assessing the annual loading of phosphorus and nitrogen versus mean retention time of water and mean annual concentration of phosphorus, nitrogen, Secchi disk, and chlorophyll *a* in the reservior.

Availability of metals to the biota was estimated by analyzing samples of water, sediment and fish tissue collected from Grand Lake. Water samples were analyzed via atomic absorption for arsenic, selenium, mercury, lead, copper, cadmium, iron and zinc, sediment for the same with the exception of arsenic and selenium and fish tissues were analyzed for cadmium, lead and zinc. Levels of metals in kidney and liver tissue were compared between fish caught from an upper and lower station on the lake. Sediment samples were collected from four stations on the lake and extracted at pH 4, 8 and 10 for use in bioassays with *Ceriodaphnia dubia*, *Daphnia magna*, *Hyallela azteca*, and *Pimephales promelas*.

Findings and Conclusions: Levels of metals were significantly higher in the sediment from the uppermost station when compared to the lowermost station. Significant differences existed in levels of zinc in kidney and liver tissue sampled from fish taken from the upper and lowermost stations. No difference in survival or reproduction of *C. dubia* during - 7-day test of lake column water from the four lake stations was observed. Sediment extracts produced no toxicity to *H. azteca* or *C. dubia* in a 48-hour assay. Sediment from Station 4 when extracted at pH 4 produced a mean of 83% mortality among three replicates of *D. magna*. Significant mortality in a 7-d Fathead Minnow Embryo-Larval Survival and Teratogenicity Assay was observed for sediment from Station 4 when extracted at pH 8.

The mean annual concentration of phosphorus and chlorophyll *a* measured at the upper end, Elk River, and Honey Creek arms of Grand Lake were indicative of eutrophic conditions within these sections. A gradient in trophic status was evident in the epilimnetic strata of the lake, i.e., from eutrophic at the upper end to oligotrophic at the lower end. The entire lake was affected by eutrophication at the upper end as evidenced by the presence of anoxic conditions in the hypolimnion during the summer stratification period. The principle investigators recommend that the eutrophication process be controlled or reversed by reducing phosphorus input to the lake from both point and nonpoint sources.

Acknowledgements

The principle investigators, S. L. "Bud" Burks and Jerry Wilhm, wish to publicly express their appreciation for the conscientious effort and dedication of the graduate research assistants and technicians who worked on this project. Denise Hampton (M.S. Env. Sci.), Noble Jobe (M.S. Zoology), Doug Reed (Ph.D. Sociology) and Deldi Schut (M.S. Env. Sci.) performed the bulk of the work and deserve recognition for their efforts. The technical staff of the OSU Water Quality Research Lab, Elaine Stebler, Sarah Kimball, Bob Johnson, Liza Robertson, Hildi Overcash, Garry Yates also participated in the collection of field samples, analyses of samples, data analysis, and report preparation.

The staff of the Oklahoma Water Resources Board were extremely helpful and we wish to extend our appreciation to Dave Dillon and Shawn Simpson. We wish to thank a former employee of the OWRB, Jerry Black for his assistance during the early startup stages of the project.

Johm Mott, a part-time OWRB employee, of Miami, OK was very instrumental in assisting us during the early stages of locating sampling sites and access to the lake. His knowledge of the local environment, especially the lake, saved us many hours of travel and collecting time. John also helped collect the fish for metal residue analyses.

We wish to acknowledge the cooperation of the OSU Cooperative Fisheries and Wildlife Unit staff, Dr. Al Zale, and graduate research assistants; Vince Travenichek, Ken Sorenson, Todd Adornato and Jan Mord. They provided us with additional physico-chemical data and with fish from Grand Lake.

The Grand River Dam Authority were extremely cooperative and provided copies of their data collected for application for renewal of the hydrological generating facility at Pensacola Dam. Gary Hunt of the Benham Group, Tulsa, OK, acted as liaison between us and GRDA. We wish to extend a personal note of appreciation for his considerate and prompt responses to requests for data.

Land use data and maps for Craig, Delaware, Ottawa, and Mayes Counties in Oklahoma were provided by Ron Treat and Darrel Hammond of the USDA Soil

Conservation Service office in Stillwater, OK. Land use data for southwestern counties in Missouri was provided by the Missouri Dept. of Natural Resources.

EXECUTIVE SUMMARY

Introduction: Grand Lake of the Cherokees is located in northeastern Oklahoma (Ottawa and Delaware Counties) and was formed by the Grand River Dam Authority (GRDA) in 1940 through the construction of Pensacola Dam on the Grand Neosho River. Grand Lake is Oklahoma's most popular tourist and recreation spot. It is the third largest reservoir in the state in both capacity and surface area. At normal pool elevation, Grand Lake has a mean depth of 36 feet, a maximum depth of 164 feet, covers 46,500 acres and holds 1,672,000 acre-feet of water.

The drainage basin above the dam includes the Grand Neosho River, Spring River and Elk River. The Spring confluences with the Neosho River just above Grand Lake. The combined rivers are called Grand River downstream of the lake. The total drainage area of Grand Lake is 10,298 square miles (Figure 1).

Historically, Grand Lake's fishery and water quality have been excellent. The fishery has been one of the best in Oklahoma with an average unadjusted fish crop of 445 pounds per acre since 1949. However, in the past decade, contamination of the Neosho and Spring rivers with acidic waters seeping from abandoned lead and zinc mines has greatly increased the potential for deterioration of water quality. Another potential water quality problem in Grand Lake has been the development of algal blooms and other indications of enrichment in the Honey Creek and Elk River arms and occasionally other arms of the lake. Knowledge of and concern over these potential problems led the Oklahoma Water Resources Board (OWRB) to prepare and submit an application for grant money, to conduct a Phase I Lake Study, to the U.S. Environmental Protection Agency (EPA). The application was approved and the OWRB contracted much of the technical work associated with the study to Oklahoma State University. A plan of work was developed and the study initiated in the spring of 1987.

The Phase I diagnostic/feasibility study of Grand Lake, which was conducted primarily from the Spring of 1989 through the Fall of 1990 was made possible through a $100,000.00 Clean Lakes Assistance Grant from the EPA. This study is part of an ongoing, federally-funded effort designed to restore the recreational uses of

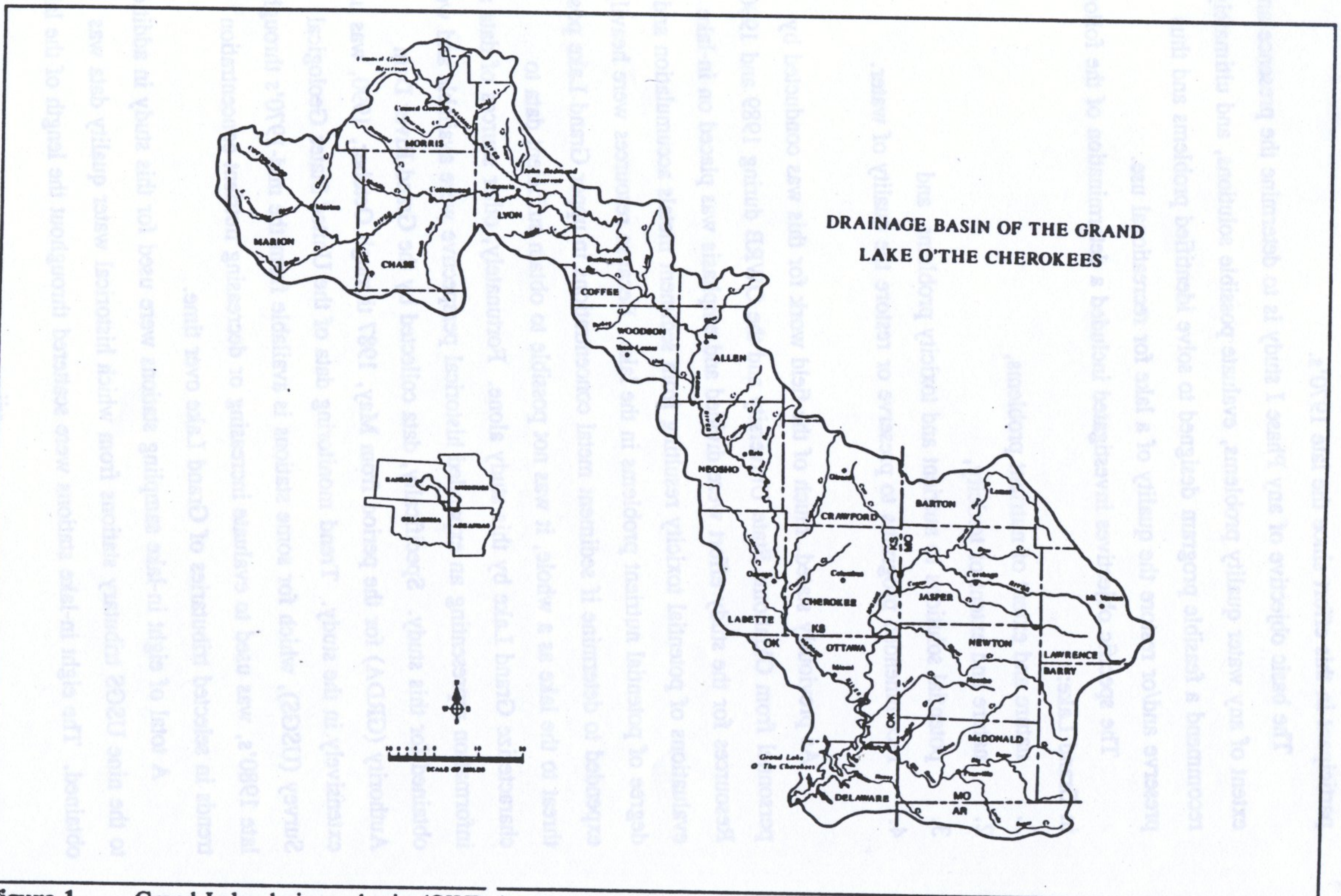

Figure 1. Grand Lake drainage basin (OWRB).

lakes and reservoirs in the United States. The state of Oklahoma has been a participant in this effort since the late 1970's.

The basic objective of any Phase I study is to determine the presence and/or extent of any water quality problems, evaluate possible solutions, and ultimately to recommend a feasible program designed to solve identified problems and thus preserve and/or restore the quality of a lake for recreational use.

The specific objectives investigated included a determination of the following in Grand Lake:

1. nature and extent of nutrient problems,
2. nature and extent of toxicity,
3. potential solutions to nutrient and toxicity problems, and
4. recommended programs to preserve or restore the quality of water.

As previously stated, much of the field work for this was conducted by personnel from Oklahoma State University and the OWRB during 1989 and 1990. Resources for the study effort were divided and emphasis was placed on in-lake evaluations of potential toxicity resulting from sediment metals accumulation and the degree of potential nutrient problems in the lake. Because resources were heavily expended to determine if sediment metal concentrations in upper Grand Lake posed a threat to the lake as a whole, it was not possible to obtain sufficient data to characterize Grand Lake by this study alone. Fortunately, other sources of data and information representing an expanded historical perspective were available and were obtained for this study. Specifically, data collected by the Grand River Dam Authority (GRDA) for the period from May, 1987 through October, 1990, was used extensively in the study. Trend monitoring data of the United States Geological Survey (USGS), which for some stations is available from the mid-1970's through the late 1980's, was used to evaluate increasing or decreasing nutrient concentration trends in selected tributaries of Grand Lake over time.

A total of eight in-lake sampling stations were used for this study in addition to the nine USGS tributary stations from which historical water quality data was obtained. The eight in-lake stations were scattered throughout the length of the lake as illustrated in Figure 2. Four of the stations were established in the main body of Grand Lake (stations 1-4) while four (stations 5-8) were established by the GRDA in major arms (Figure 2).

Traditional limnological methods of data collection and analysis as well as specialized toxicity testing and fish tissue analyses were used during this study. Both the methods of collection and of analysis are described in detail in the main body of the Phase I report.

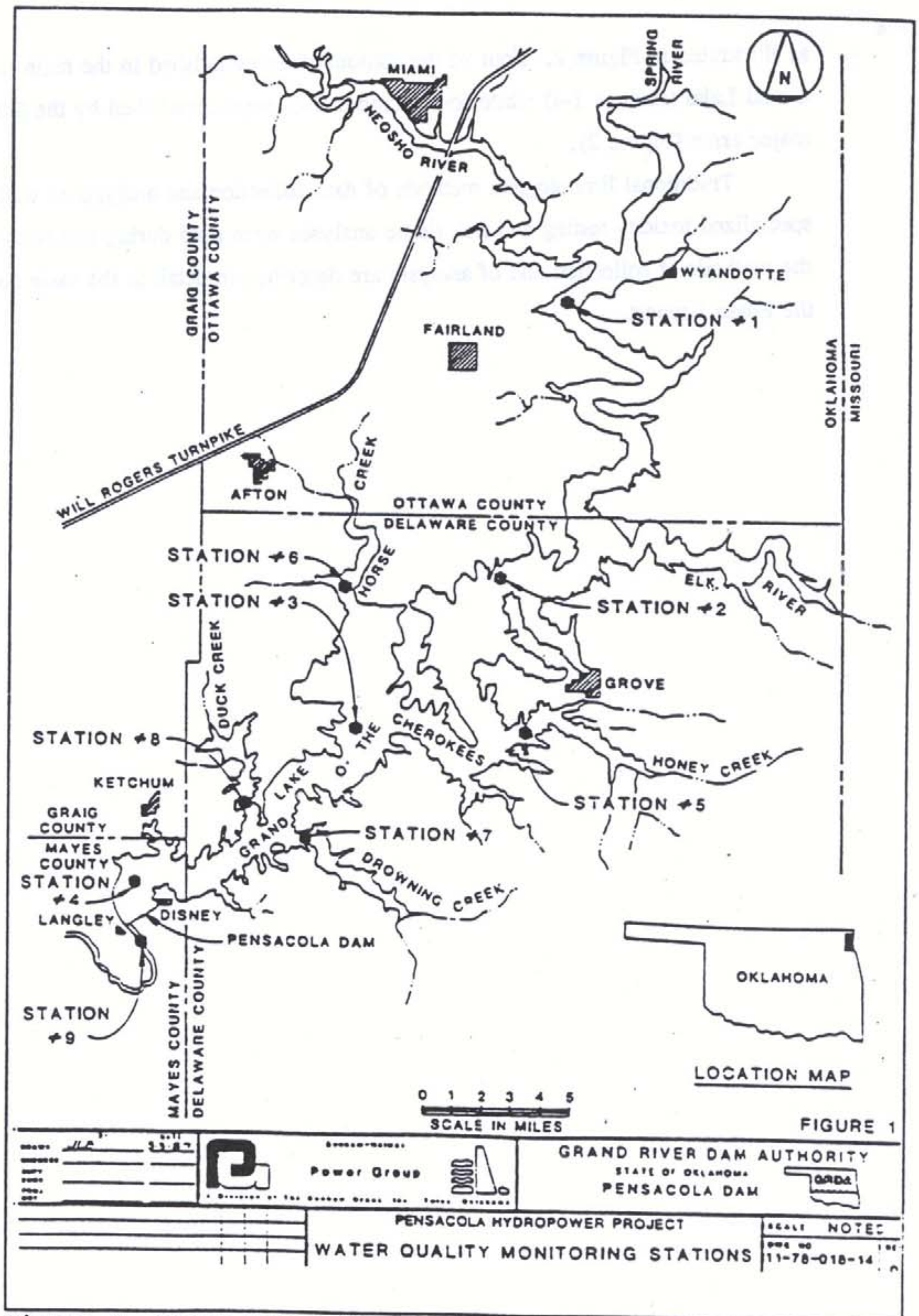

Figure 2 Grand Lake with sampling stations (GRDA).

Findings and Conclusions.

Potential metals contamination in the upper end of Grand Lake has been a concern since the early 1980's. In 1983, the Environmental Effects Subcommittee of the Tar Creek Task Force released a report prepared by the U.S. Fish and Wildlife Service National Reservoir Research Program, "*Effects of Acid Mine Drainage from Tar Creek on Fishes and Benthic Macroinvertebrates in Grand Lake, Oklahoma*". Conclusions from that work specific to Grand Lake indicated that species composition and standing crops of fish showed no effects of heavy metal contamination. Furthermore, the report concluded that heavy metals would continue to be accumulated in sediments although the accumulation was not judged to be dangerous to the aquatic community of Grand Lake at the time the report was written. The report also recommended periodic monitoring to evaluate long-term biological effects of metal contamination.

Findings of the current metals evaluation tent to support the earlier conclusion in that there were no significant toxic effects upon sensitive species of small fish or micro-crustaceans exposed to water samples collected from various regions of the lake. The levels of lead and zinc were significantly higher in sediment from the upper end than from the downstream portion of Grand Lake. However, the metals appear to be chemically bound to the sediments since toxic levels of metals could not be extracted from lake sediments at ranges of pH that exist in the lake, i.e., from minimum of 6.8 to maximum of 8.8. Toxic levels of zinc could be extracted from sediments at upper end of the lake at pH's of 6 or less as demonstrated through laboratory experiments, but the pH of the lake should not drop below 6 under normal circumstances.

The upstream portion of Grand Lake is impacted by heavy metal contamination from the abandoned lead-zinc mines; however, the contamination appears to be confined to sediments in the upper reaches of the lake and does not pose an immediate threat to the overall quality of water in Grand Lake.

Under extreme conditions, continued metals transport from upstream tributaries and/or increased eutrophication might decrease pH from the currently measured low of 6.8 units to a "critically" low pH of 6.0. Dissolution of metals from the sediment would potentially become a serious problem in Grand Lake under conditions of low pH. Again, it should be stressed that a drop in pH to 6.0 units, which would probably result in toxic releases of zinc, is not a likely occurrence.

Data collected from upstream tributaries by USGS were analyzed to determine if nutrients such as nitrogen and phosphorus were increasing, decreasing, or remaining the same over time. The findings from this evaluation were somewhat mixed. Overall, the results of the trend tests on the Neosho River indicate that total phosphorus levels have been increasing over time. This is evident at USGS 07183500 at Parsons, Kansas and at USGS 07185000 at Commerce, Oklahoma. However, the trend tests for nitrite plus nitrate levels have indicated no significant increasing trend over time for the Neosho River. For the Spring River, trend tests on both total phosphorus and nitrite plus nitrate indicate no significant upward trend in the nutrient levels over time.

The upper end of the lake and Elk River and Honey Creek arms were judged to be eutrophic (over fertilized) when the concentration of chlorophyll *a* (an algal pigment) and nutrients such as phosphorus and nitrogen were compared with Reckhow's (1988) criteria for impoundments in Florida. The remainder of the lake was not considered to be highly enriched. However, the entire lake is being influenced by eutrophication processes occurring in the upper end of the lake. The lake naturally stratifies during summer due to rapid solar heating of the upper strata. The warm upper layer cannot mix with the cool denser layer on the bottom. Organic matter imported from the rivers and also from growth of algae in the sunlit upper layers, falls into the bottom layer of the lake where it is degraded by bacteria. Bacterial degradation of these organic compounds use all of the available oxygen from the bottom layer of the lake. This produces a condition where there is no oxygen available for fish to breathe and therefore the bottom layer of the lake cannot support desirable forms of aquatic life during the summer. These anoxic conditions also affect the chemistry of phosphorus within the lake, resulting in a recirculation of phosphorus from the sediments as well as the input from external sources.

Phosphorus acts as a nutrient to stimulate growth of algae. As a result, the lake is rapidly accelerating into eutrophic conditions and decreasing water quality.

In summary, it appears that the recreational uses of Grand Lake (swimming, boating, fishing) as a whole are relatively intact. However, continued degradation of water quality due to excessive nutrients and metals could lead to serious impairments in use of the lake. Metals which are currently bound to sediments in the upper end of Grand Lake should not be disturbed. Physical disruption of the bottom sediments, such as would occur during dredging, could lead to an environmental crisis in Grand Lake through release of toxic concentrations of metals into the water column. Monitoring of water quality in Grand Lake should be continued on at least a periodic basis and remedial efforts expanded if conditions of the lake worsen over time.

RECOMMENDED REMEDIATION EFFORTS.

Heavy Metal Contamination. We recommend the efforts to prevent heavy metal contamination from the abandoned lead and zinc mines be continued. The current level of contamination appears to have caused some localized impacts in the upper end of Grand Lake. However, continued heavy metal contamination coupled with eutrophication could produce conditions which would accelerate transport of metals throughout the remainder of the lake and the Grand River basin.

Eutrophication. We recommend two voluntary programs be initiated to attempt to reduce phosphorus contamination within the basin:

1. Voluntary switch to non-phosphate detergents by all lake side residents and the cities of Grove and Miami, OK.
2. Implementation of a best management practices upstream from Grand Lake to minimize contributions of phosphorus in surface water runoff from agricultural fertilizer applications.
3. Continue to work with point source dischargers, to the extent possible within the watershed, to minimize discharges of nutrients including phosphorus.

RATIONALE.

If the concentration of phosphorus was reduced in Grand Lake, how would this affect water quality?

Reckhow (1988) used data from 80 lakes and reservoirs in the southeastern United States to develop a generalized equation relating concentration of phosphorus and nitrogen to production of algae as measured by chlorophyll *a* concentration. We used Reckhow's general equations to calculate similar relationships for Grand Lake and as a tool for predicting future algal density if phosphorus was reduced.

The growth of algae is generally increased by an increased level of phosphorus in the water. In fact, high concentrations of phosphorus often leads to extensive growth of blue-green algae, an undesirable, odor-producing form of algae. Extensive growths of blue-green algae do not presently exist in Grand Lake and our recommendations include taking measures to prevent development of nuisance blue-green algal blooms.

The measurement of chlorophyll *a*, a green pigment found in the algae, provides an index of the density of algae. Low concentrations of chlorophyll *a* indicate a low density of algae and vice versa. Since the growth of algae is increased by phosphorus, we predict a reduction in phosphorus would reduce the density of algae and chlorophyll *a* (Figure 3).

One of the problems associated with algal growths is a reduction in the clarity of the water. Thus, the aesthetic quality of the water is decreased and the lake is no longer as attractive to visitors and residents. Many of the more popular recreational lakes in the northcentral United States have low concentrations of phosphorus and therefore low density of algae. In contrast, some enriched lakes are extremely green and are not as attractive for some recreational activities. Grand Lake is intermediate to these extremes and our recommendations include implementation of measures that would prevent further deterioration in water quality.

The clarity of water is easily measured by lowering a circular disk into the water and recording the depth at which the disk disappears from view. The disk is

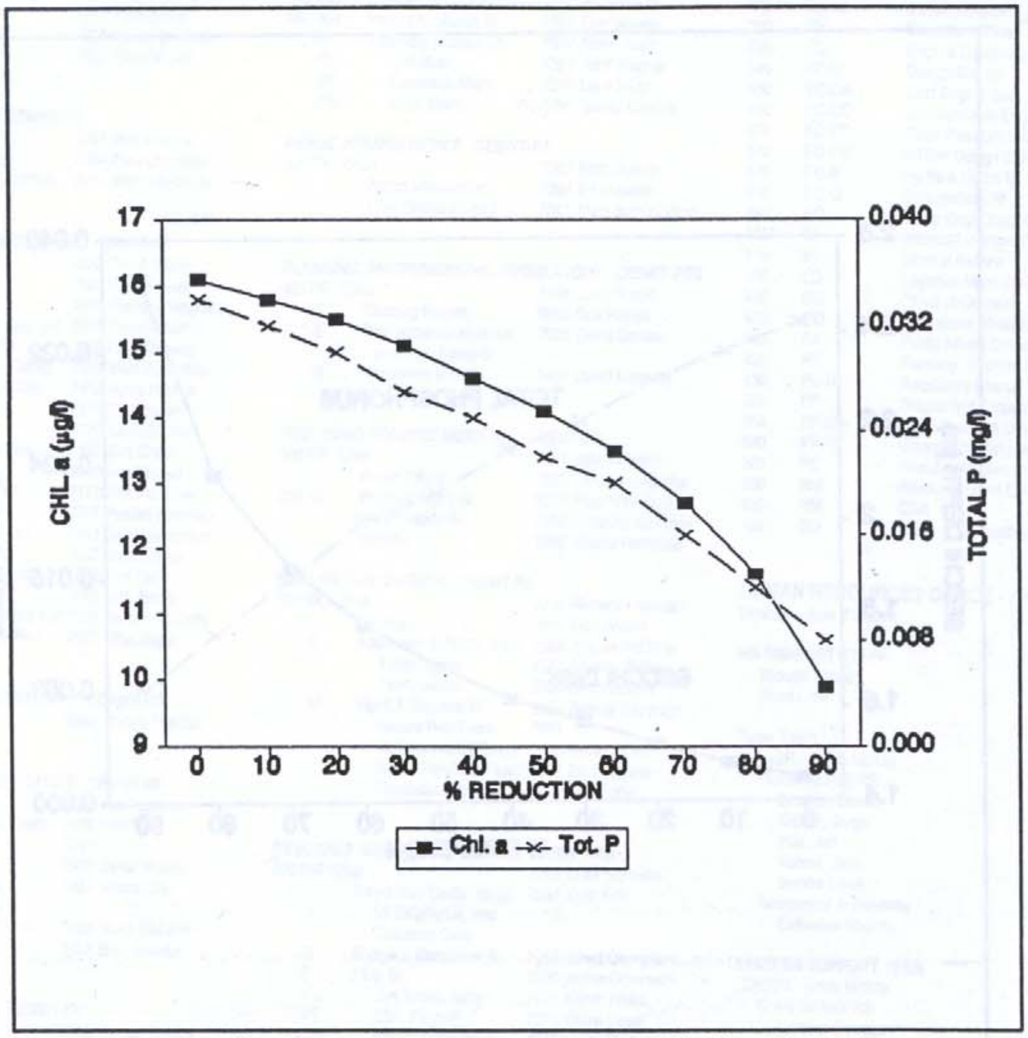

Figure 3. Predicted annual average concentration of chlorophyll *a* in response to reductions of phosphorus.

called a Secchi disk after the limnologist who developed the method. In two lakes in Michigan in summer, Secchi disk depths were generally less than 1.5 meters (about 5 feet) in an enriched lake and generally exceeded 5 meters (over 16 feet) in a nonenriched, hardwater lake.

We predict the annual average Secchi disk depth at the lower end of Grand Lake would increase in response to a reduction in overall concentration of phosphorus (Figure 4).

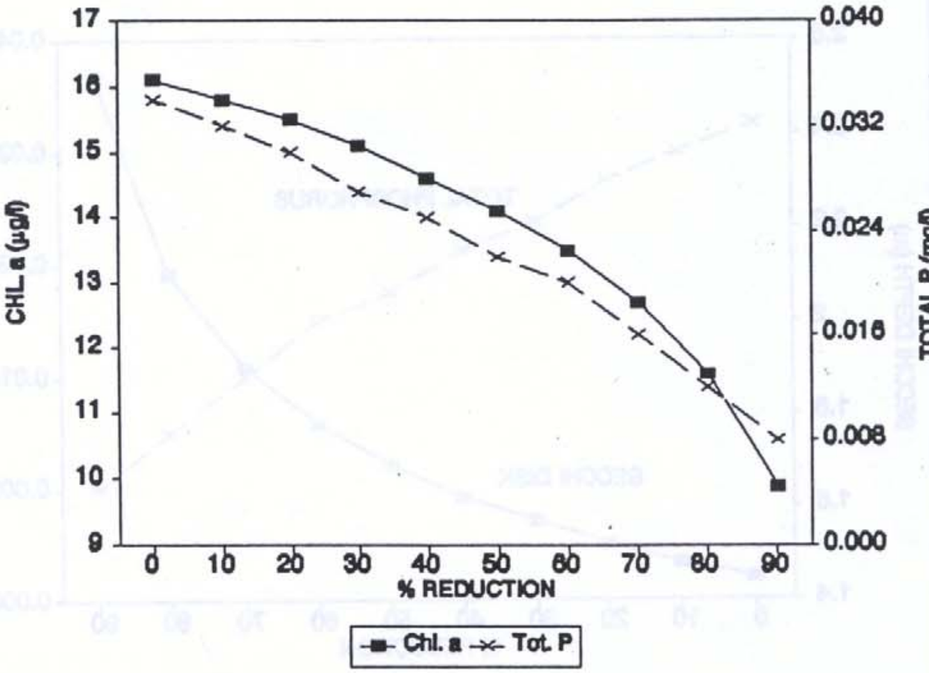

Figure 3. Predicted annual average concentration of chlorophyll *a* in response to reductions of phosphorus.

called a Secchi disk after the limnologist who developed the method. In two lakes in Michigan in summer, Secchi disk depths were generally less than 1.5 meters (about 5 feet) in an enriched lake and generally exceeded 5 meters (over 16 feet) in a nonenriched, hardwater lake.

We predict the annual average Secchi disk depth at the lower end of Grand Lake would increase in response to a reduction in overall concentration of phosphorus (Figure 4).